Change Analysis of Glacier Ice Extent for Kenai Fjords National Park, Alaska

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Outline

- Objectives
- Parks involved
- Key findings
- Overall importance of the work
- Examples of glacier changes
- Issues & recommendations
- Conclusions
- Future plans

Objective and Parks Involved

- The overall objective is to measure glacier changes in Kenai Fjords and Katmai National Parks, and Lake Clark National Park & Preserve during the Landsat era (1972-present)
- Extent and and change in extent of glaciers will be measured in each decade if possible, and provided as GIS shape files so that future measurements of the glacier extents can be compared quantitatively with Landsat-derived results

General Methodology

Glaciers emanating from the Harding Icefield and the Grewingk-Yalik Glacier Complex have been studied with Landsat data from 1973, 1986 and 2002, with emphasis on those glaciers located within Kenai Fjords National Park (KEFJ)

Landsat scenes used in this work

17 August 1973	MSS (80-m resolution)
12 September 1986	TM (30 m)
29 September 2001*	ETM+ (30 & 15 m)
30 July 2002	TM (30 m)
09 August 2002**	ETM+ (30 & 15 m)

* Only used to generate a DEM.

** Only used when parts of the 30 July 2002 image were cloudy.

Summary of Key Findings

- Terminus recession was measured in nearly all of the land-terminating, lake-terminating and tidewater glaciers glaciers, with some exceptions
- These results agree with extensive measurements made in the mid- to late-1990s by University of Alaska – Fairbanks scientists (see Echelmeyer et al., 1996; Adalgeirsdóttir et al., 1998)
- The most important issues that affect our ability to measure the glacier termini accurately from space are debris-covered termini and new snowfall

Global Glacier Mass Balance Summary

North America - dramatic retreat in Alaska, Canada and the continental United States

South America - dramatic recession

Tropical areas - dramatic recession

Iceland - shrinkage since ~1890, with some advances, but recent accelerated shrinking since ~1990 due to warm summers

Scandinavia - glaciers advanced until ~2000, and are now generally retreating

European Alps - dramatic recession - 50% loss of glacier volume as compared to ~1850

Mass balance of the **Greenland and Antarctic ice sheets** is unknown

Global Glacier Mass Balance (Volume Change)

From 1961 to 2003, the thickness of "small" glaciers decreased approximately 8 meters, or the equivalent of more than 6,000 cubic kilometers of water

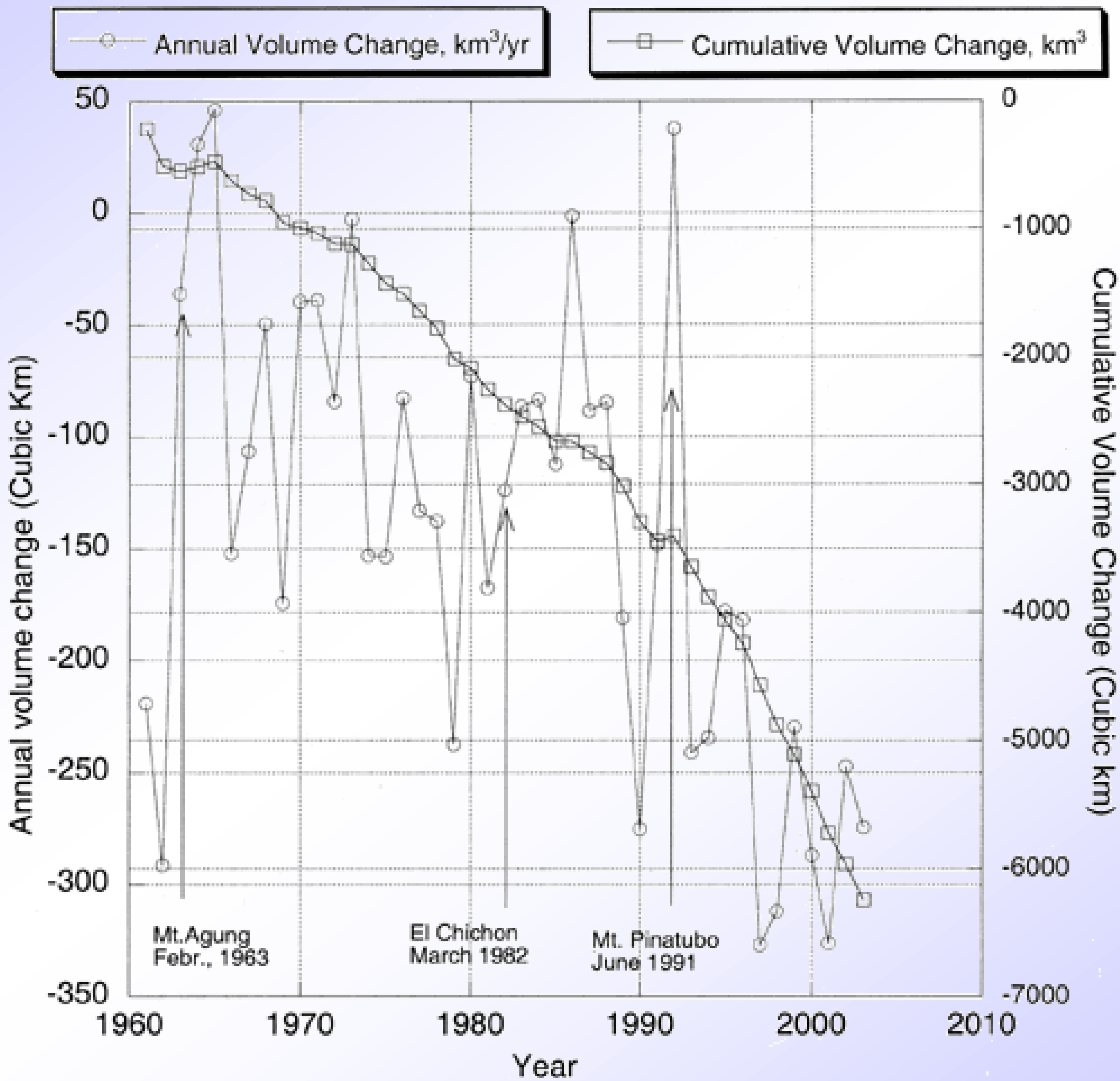


Image courtesy of Mark Dyurgerov, Institute of Arctic and Alpine Research, University of Colorado, Boulder

Estimated potential maximum sea level rise from the total melting of present-day glaciers

Location	Volume (km^3)	Potential sea-level rise (m)
East Antarctic ice sheet	26,039,200	64.80
West Antarctic ice sheet	3,262,000	8.06
Antarctic Peninsula	227,100	.46
Greenland	2,620,000	6.55
All other ice caps, ice fields, and valley glaciers	180,000	.45
Total	32,328,300	80.32

U.S. Department of the Interior
U.S. Geological Survey

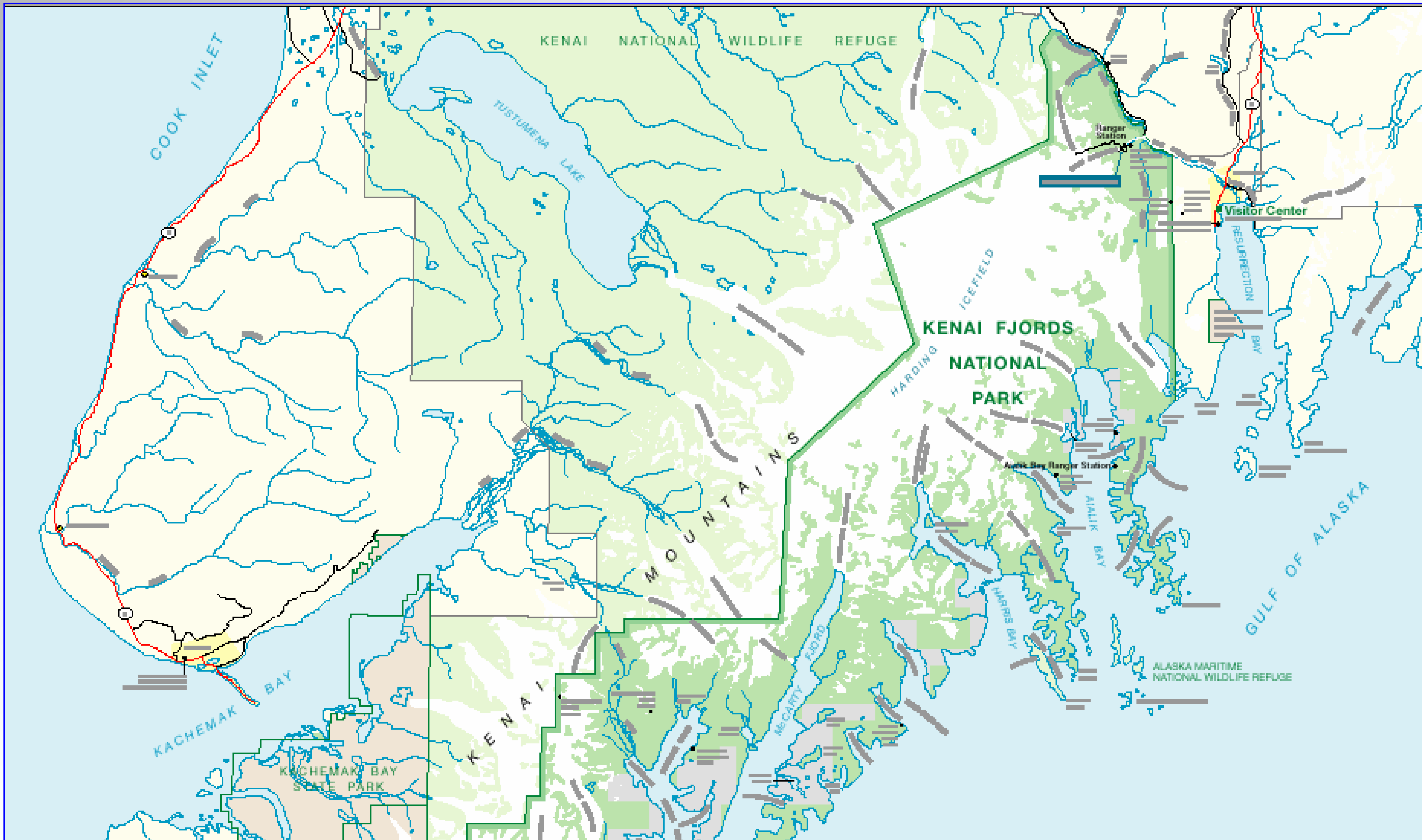
After Williams and Hall (1993)

Nearly 100-million people live within 1 m of the mean sea level!

Kenai Fjords National Park (KEFJ)

- Harding Icefield - located on Kenai Peninsula, Alaska, in the Kenai Mountains, covers an area of ~1800 km^2, about half of which lies within the boundary of KEFJ
- Harding Icefield has been thinning and shrinking since the 1950s
- More than 38 glaciers emanate from the Harding Icefield
- Most glaciers in Alaska have thinned over 100 m at low elevations and ~18 m at higher elevations in the last 40 years (Keith Echelmeyer/U Ak)

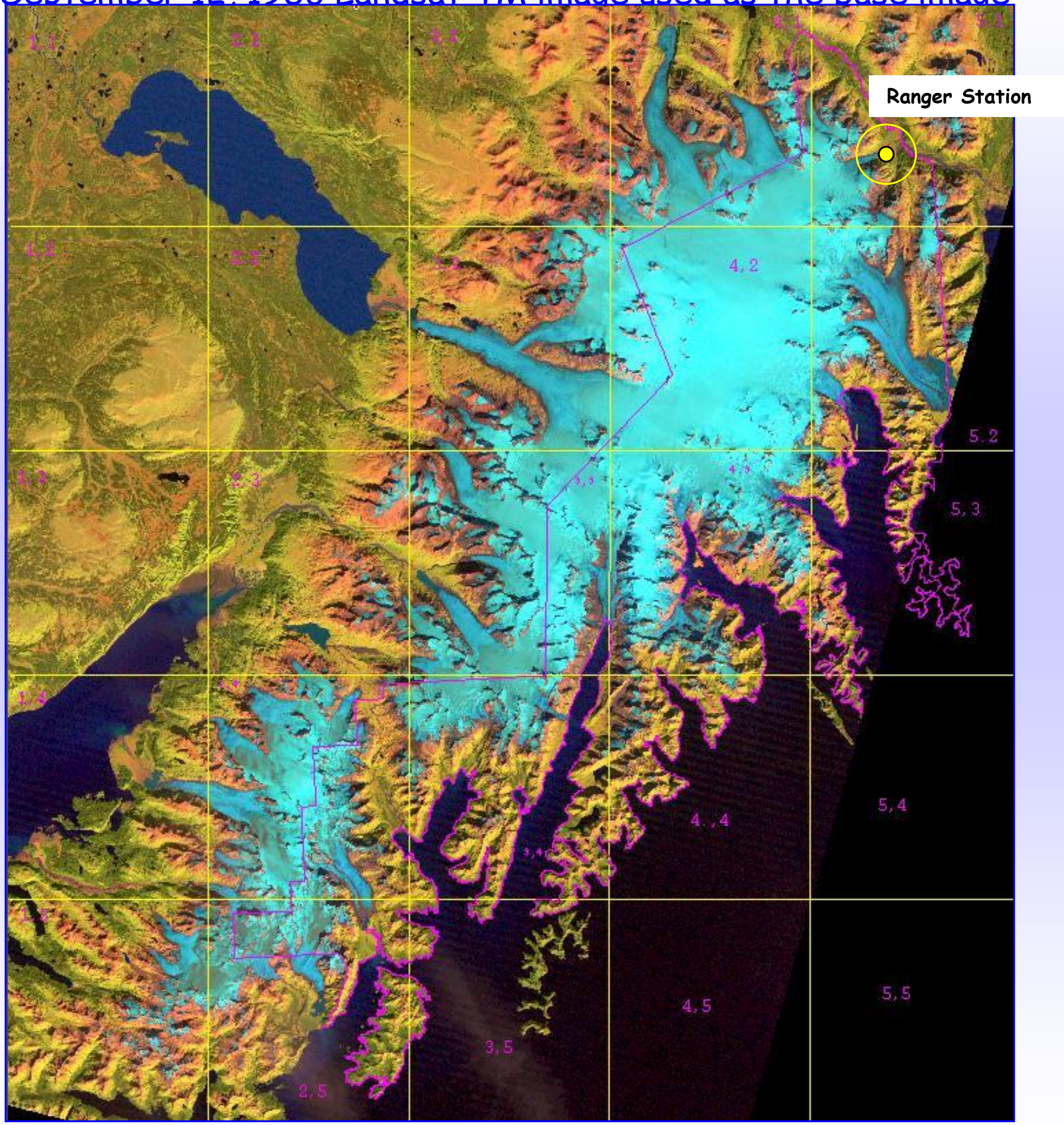
National Park Service map of Kenai Fjords National Park (KEFJ)



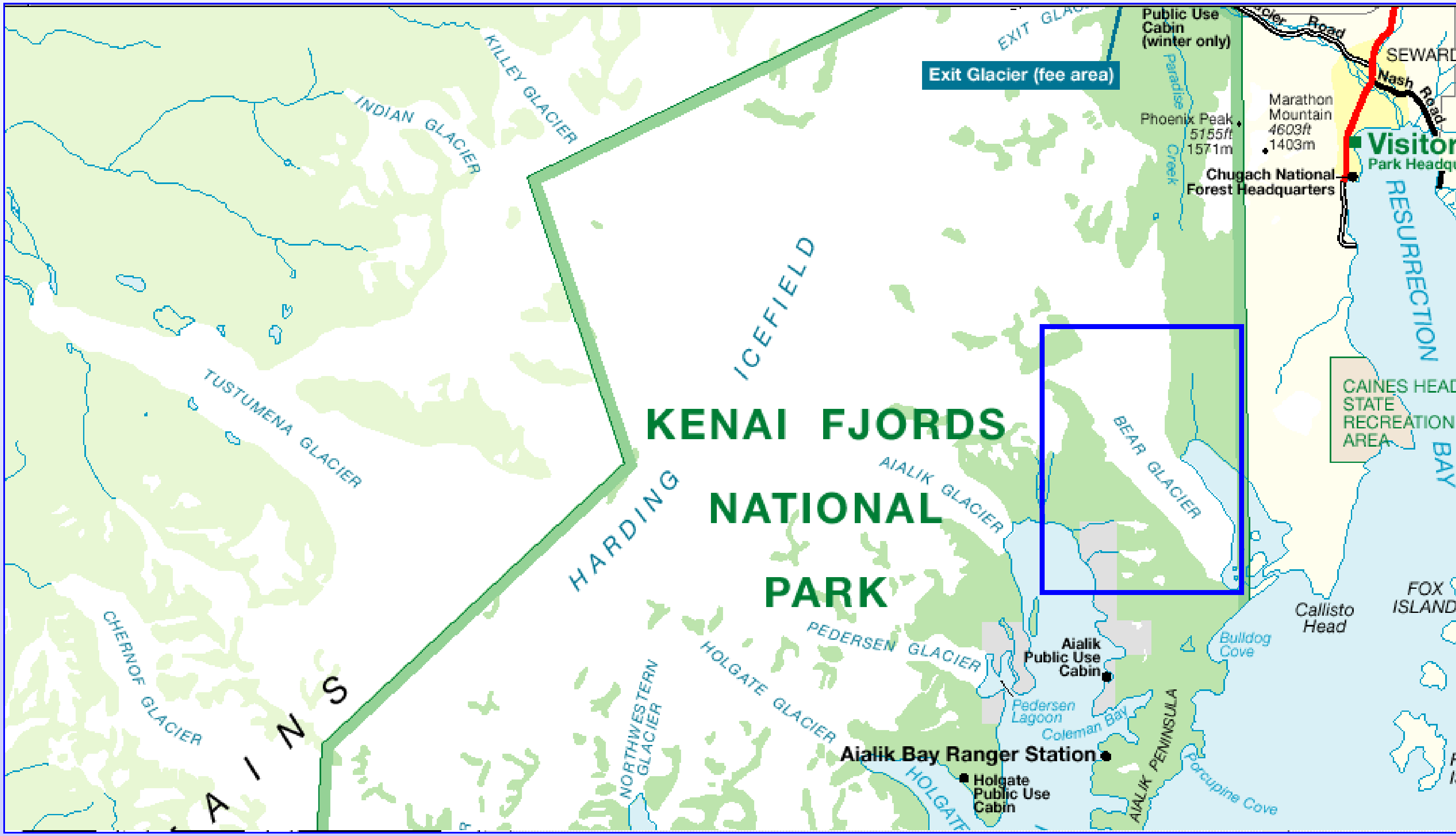
Harding Icefield and Grewingk-Yalik Glacier Complex

September 12, 1986 Landsat TM image used as the base image

Shape files were produced for this entire area from three Landsat images



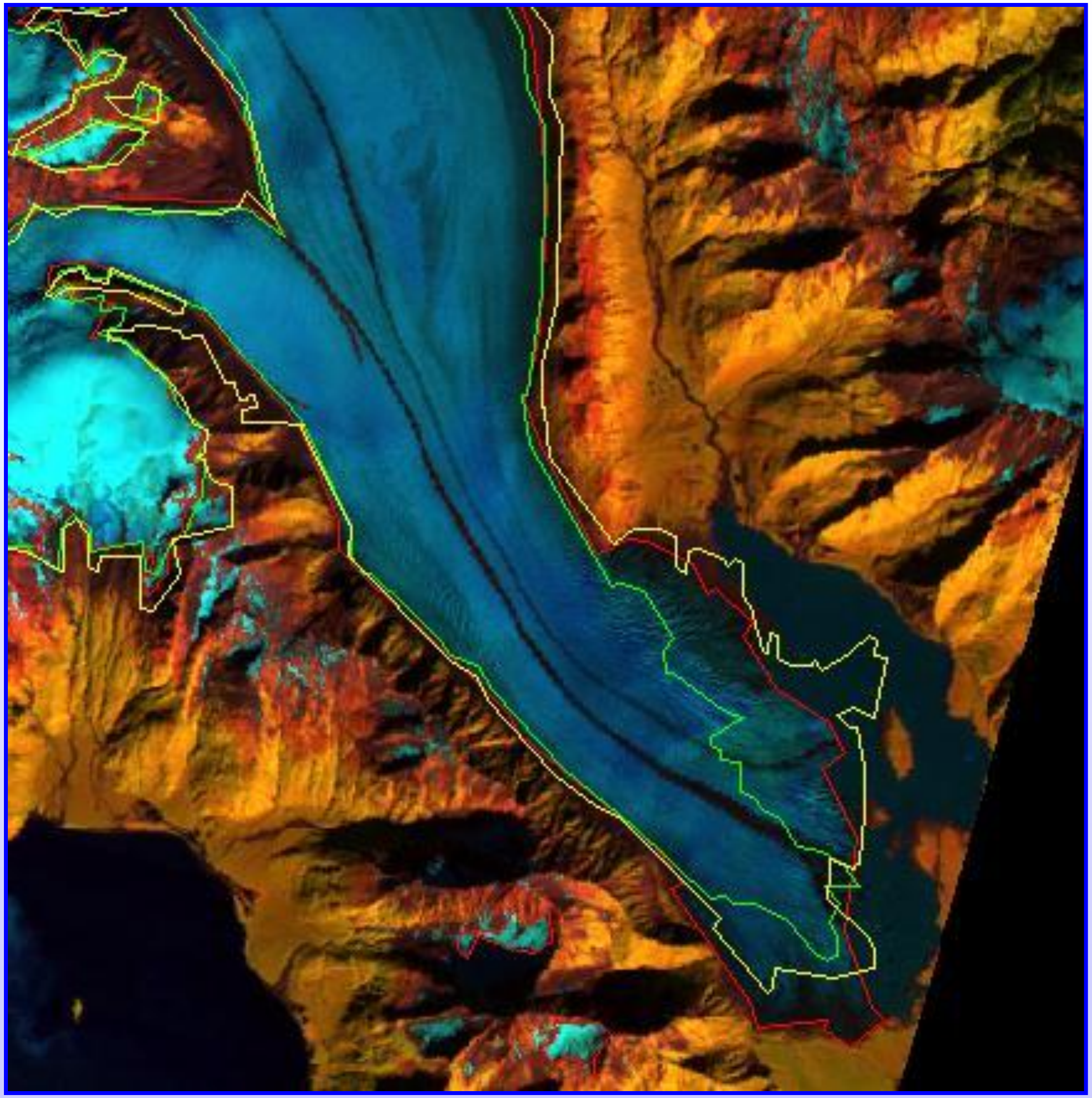
Kenai Fjords National Park boundary is shown in purple



KENAI FJORDS
NATIONAL
PARK
HARDING
ICEFIELD
Exit Glacier (fee area)
Public Use
Cabin
(winter only)
SEWARD
Nash Road
Marathon
Mountain
4603ft
1403m
Phoenix Peak
5155ft
1571m
Paradise Creek
Visitor
Chugach National
Forest Headquarters
RESURRECTION BAY
CAINES HEAD
STATE
RECREATION
AREA
FOX
ISLAND
Callisto
Head
Bulldog
Cove
KILLEY GLACIER
INDIAN GLACIER
TUSTUMENA GLACIER
CHERNOF GLACIER
AIALIK GLACIER
BEAR GLACIER
PEDERSEN GLACIER
HOLGATE GLACIER
NORTHWESTERN GLACIER
Aialik
Public Use
Cabin
Pedersen
Lagoon
Coleman Bay
Aialik Bay Ranger Station
Holgate
Public Use
Cabin
AIALIK PENINSULA
Porcupine Cove

Bear Glacier

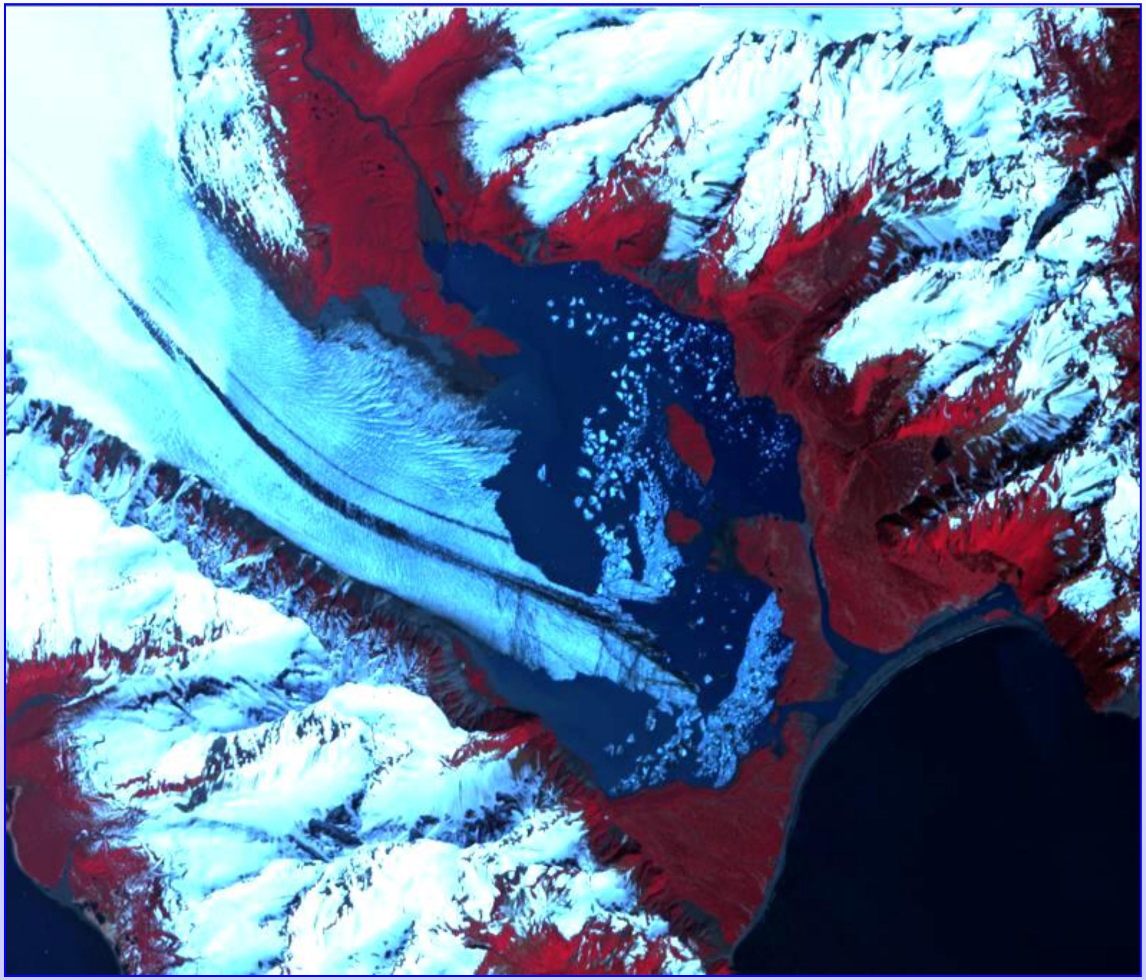
Bear Glacier (from NPS website)



1973 1986 2002

Bear Glacier

June 9, 2001 ASTER* image (15-m resolution)



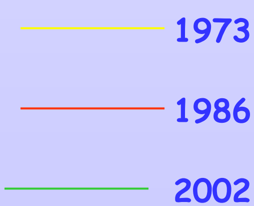
*Advanced Spaceborne Thermal Emission and Reflection Radiometer

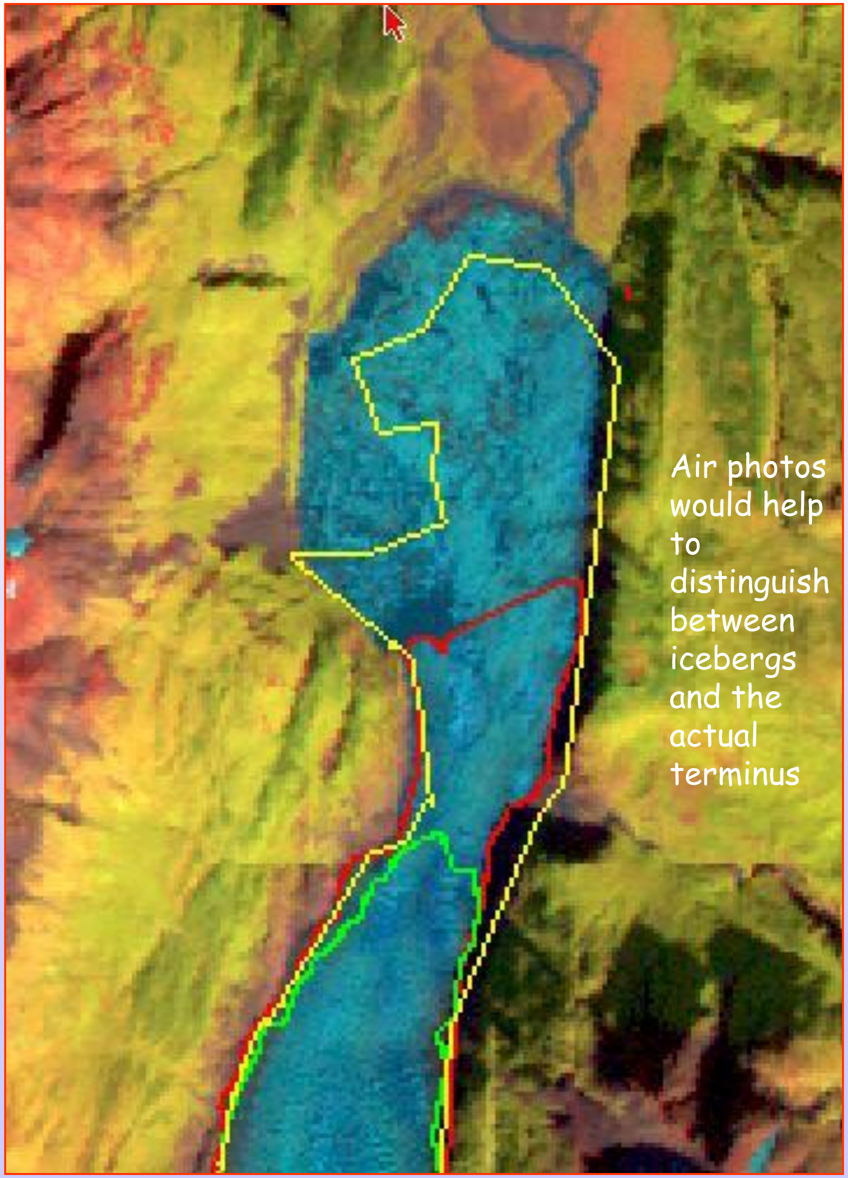
Skilak Glacier

September 12, 1986 Landsat TM image

Kenai Fjords National Park boundary is shown in purple

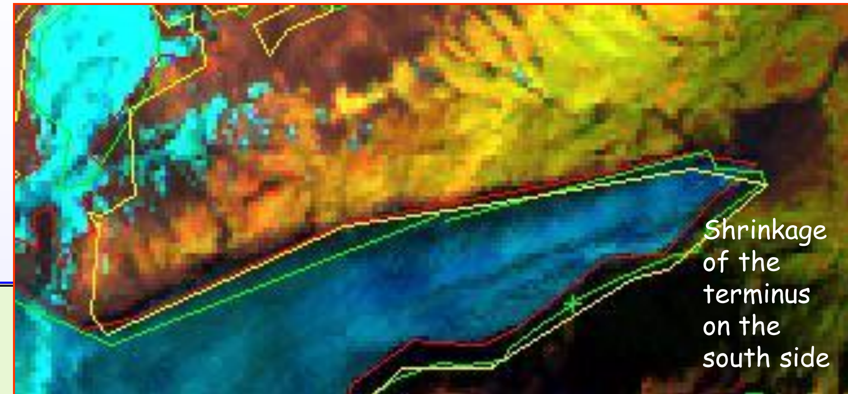
~3811±136 m recession
from 1973-2002

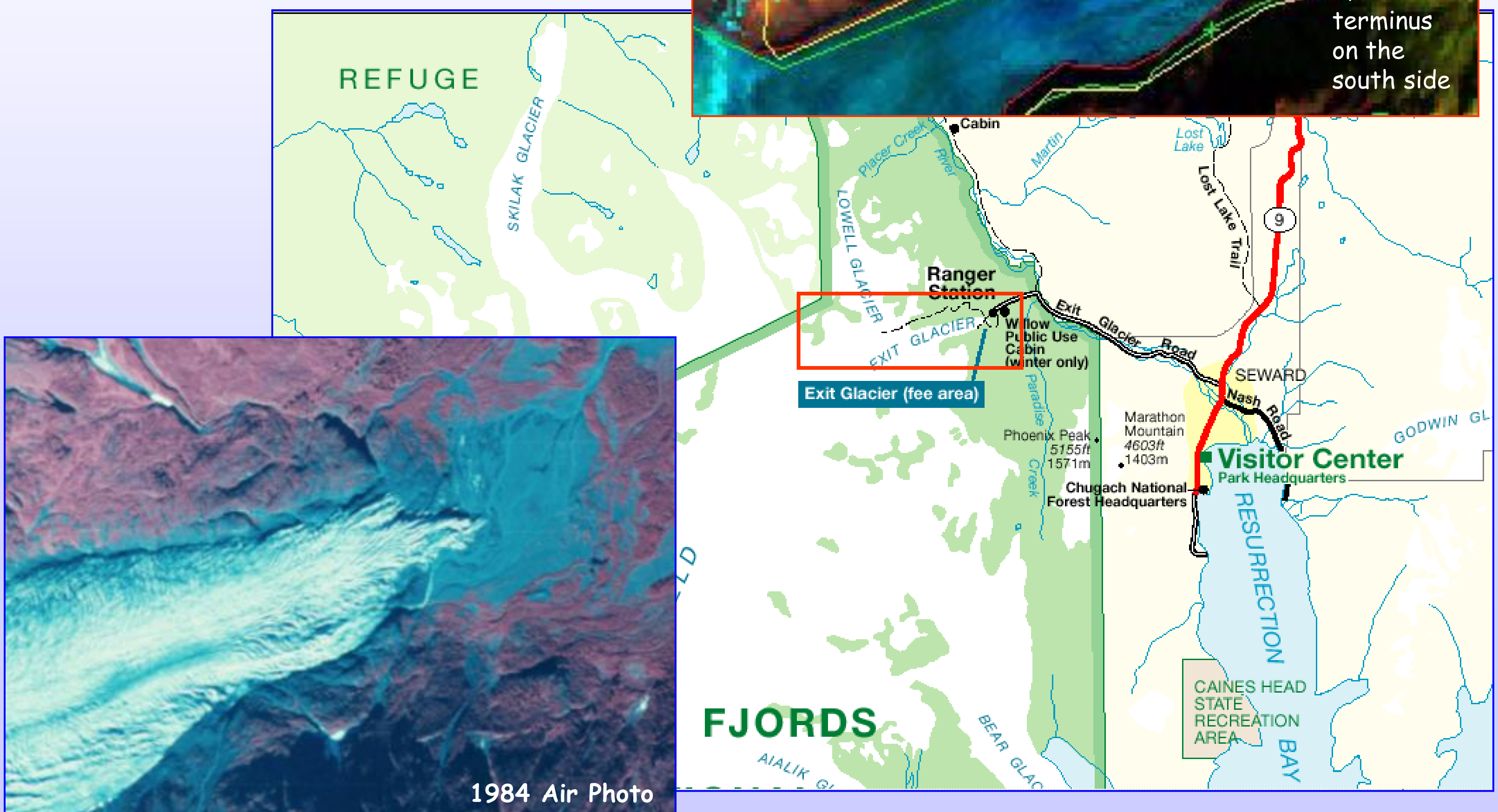




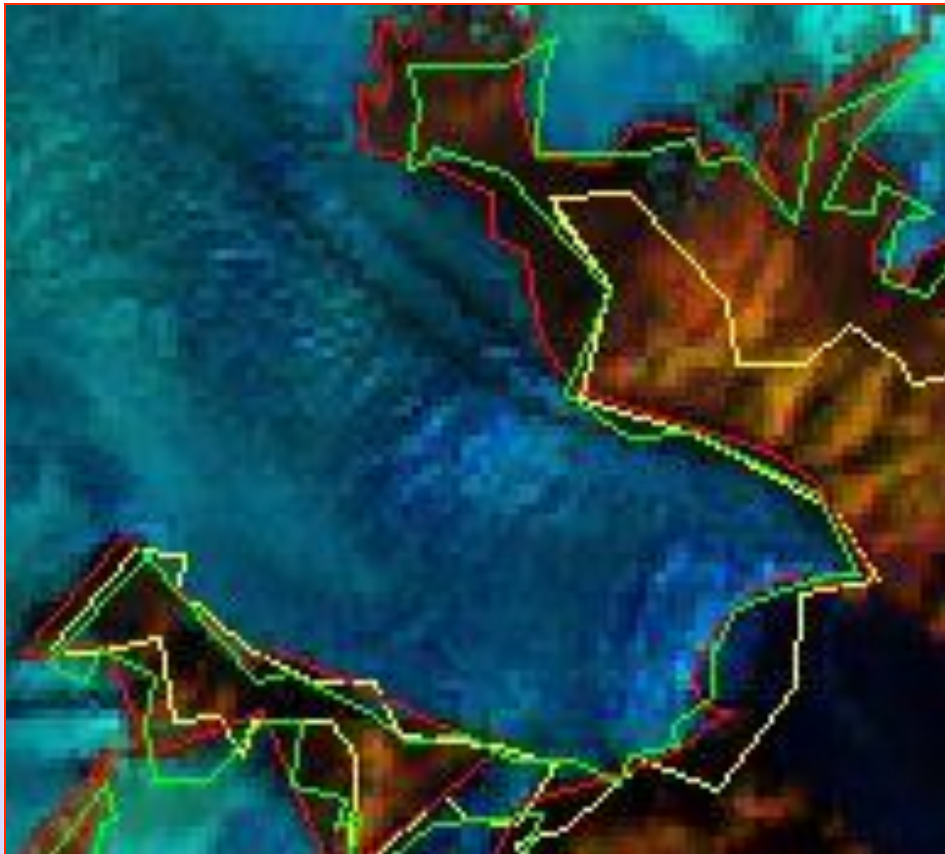
Exit Glacier

1973
1986
2002

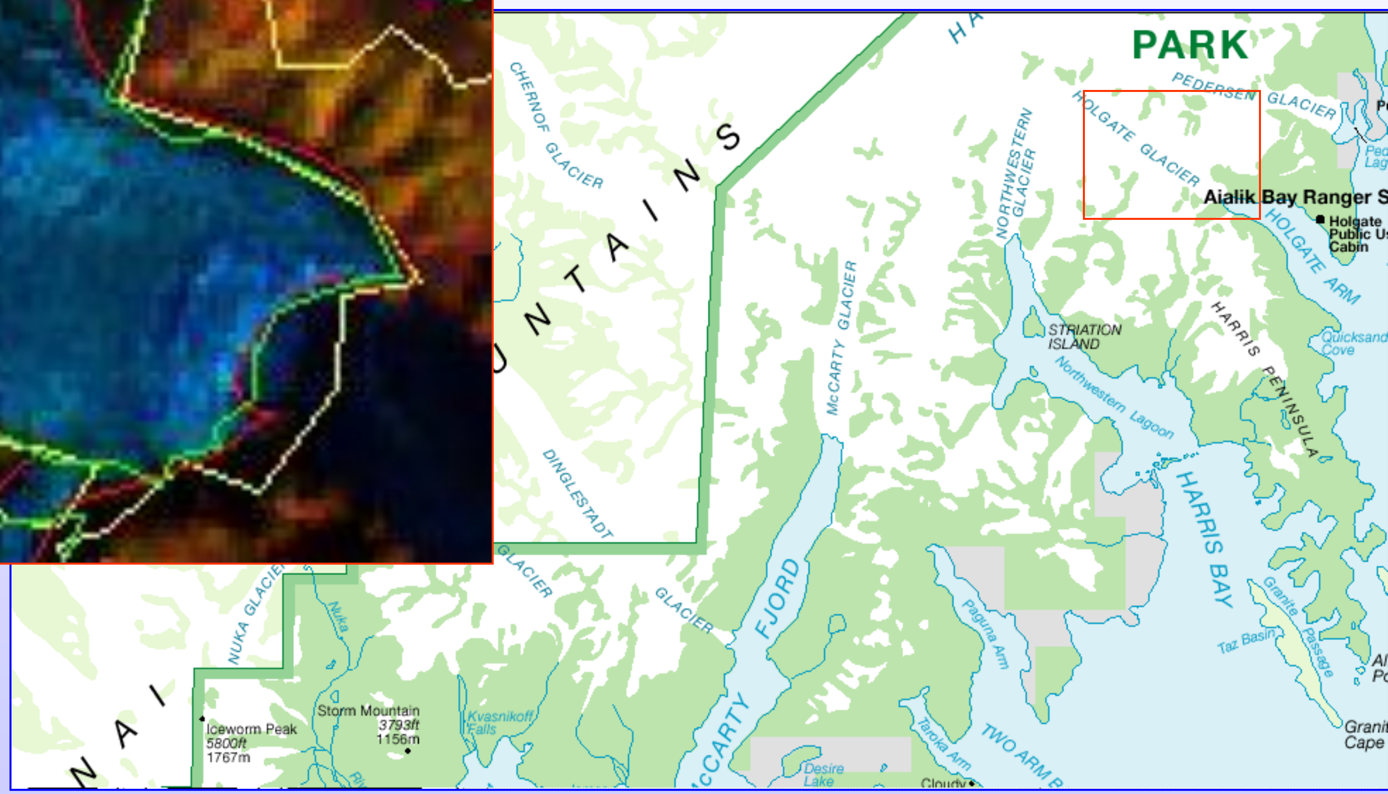




Holgate Glacier



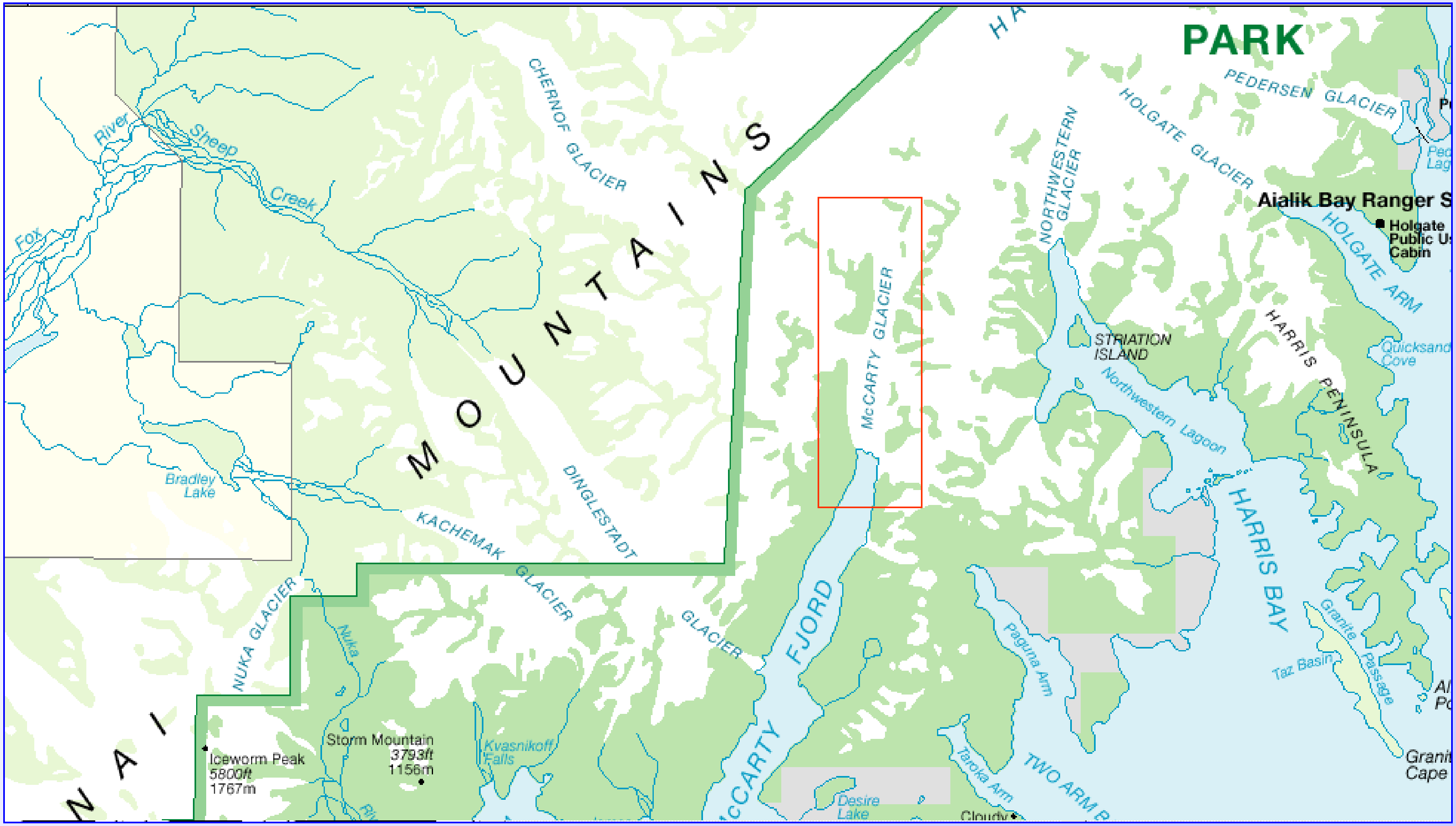
~319±136 m recession from 1973-2002



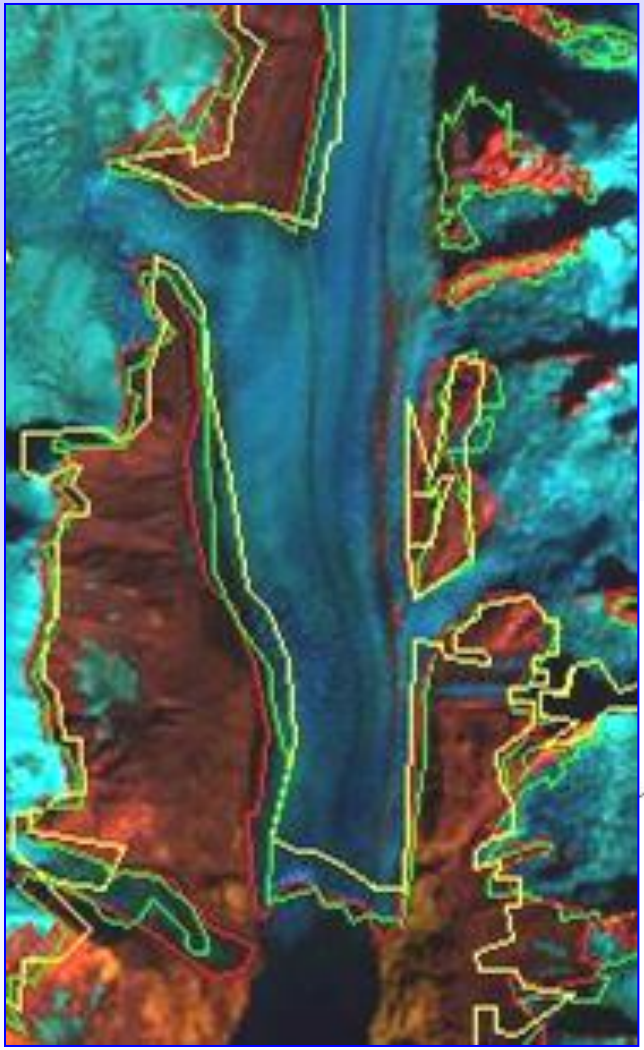
1973

1986

2002


PARK
CHERNOF GLACIER
MOUNTAINS
River
Sheep
Creek
Fox
Bradley
Lake
KACHEMAK
GLACIER
DINGLESTADT
GLACIER
NUKA GLACIER
Nuka
Storm Mountain
3793ft
1156m
Iceworm Peak
5800ft
1767m
Kvasnikoff
Falls
McCARTY GLACIER
FJORD
NORTHWESTERN
GLACIER
HOLGATE GLACIER
PEDERSEN GLACIER
Aialik Bay Ranger S
Holgate
Public U
Cabin
HOLGATE ARM
HARRIS PENINSULA
STRIATION
ISLAND
Northwestern Lagoon
Quicksand
Cove
HARRIS BAY
Paguna Arm
Taz Basin
Granite Passage
Granit
Cape
TWO ARM B
Taroka Arm
Desire
Lake
Cloudy

McCarty Glacier



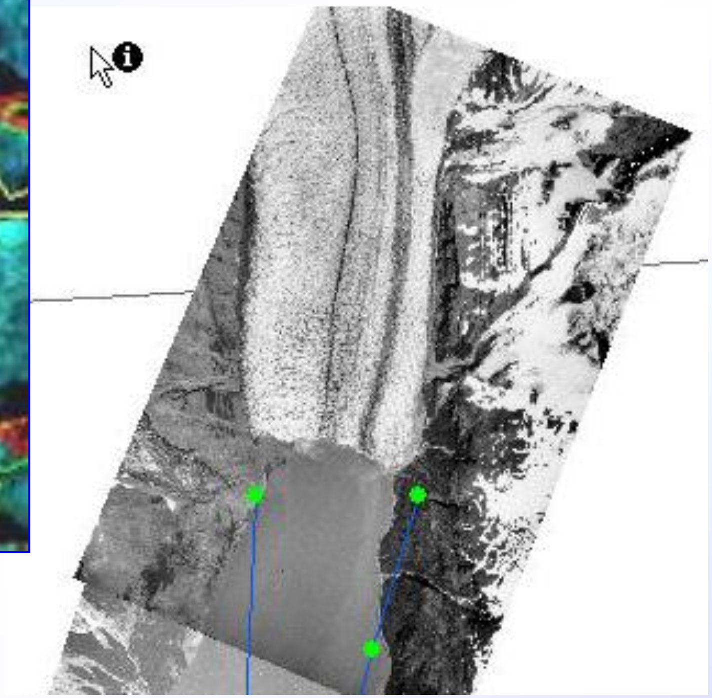
1986 TM image

1973

1986

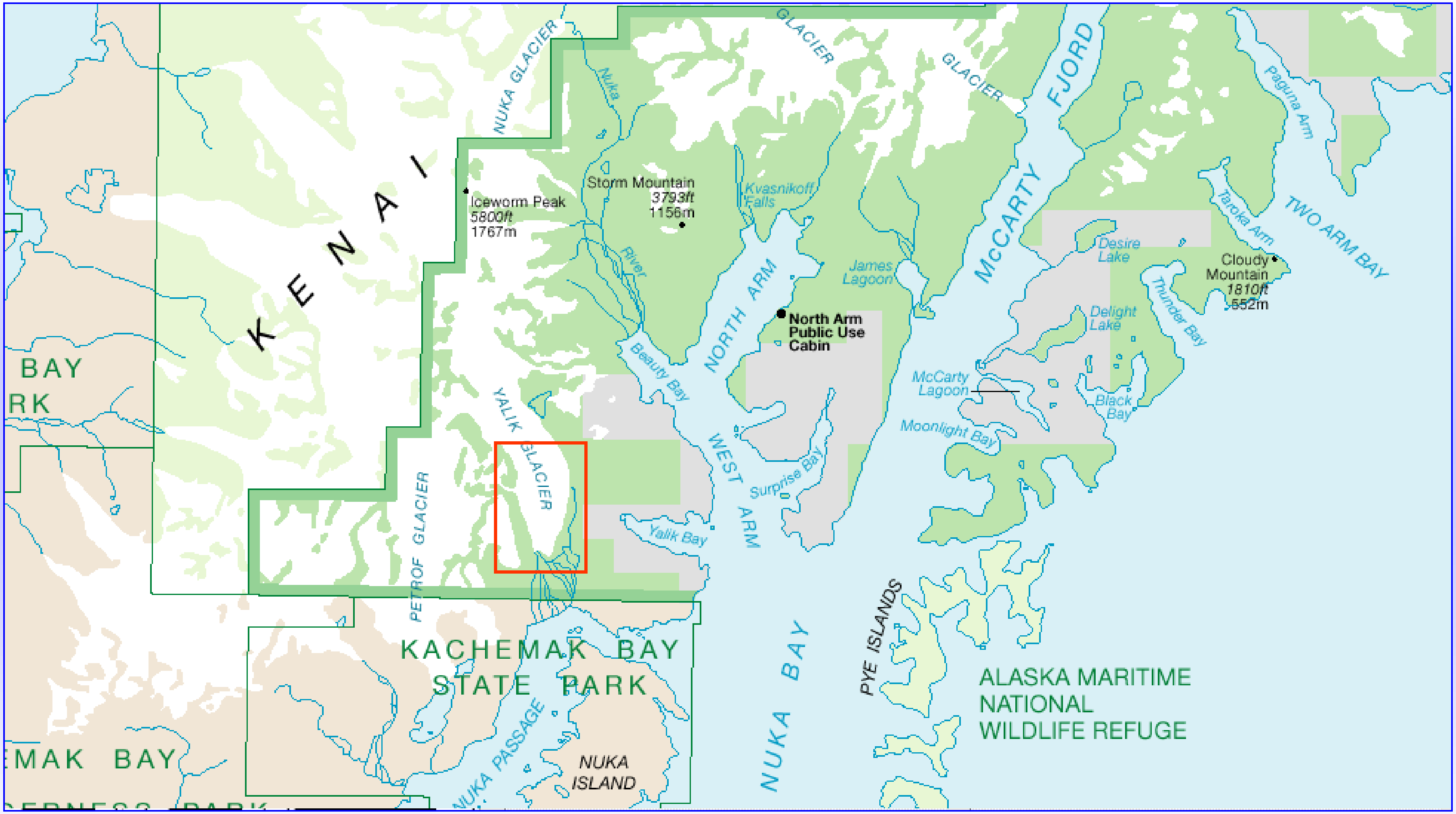
2002

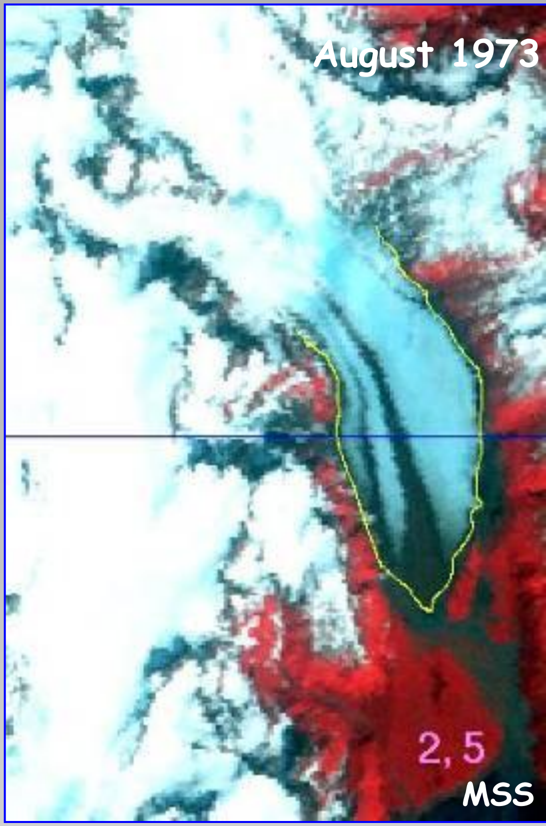
~277±136 m advance from 1973-2002

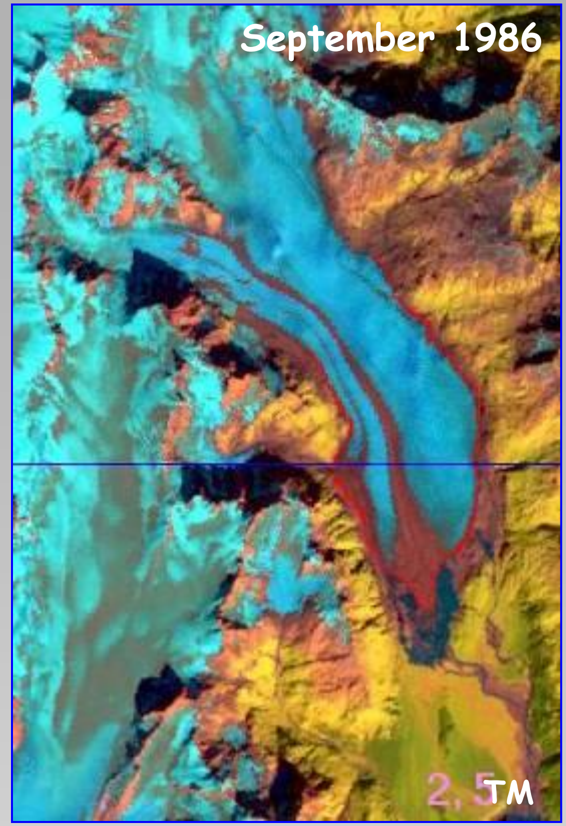


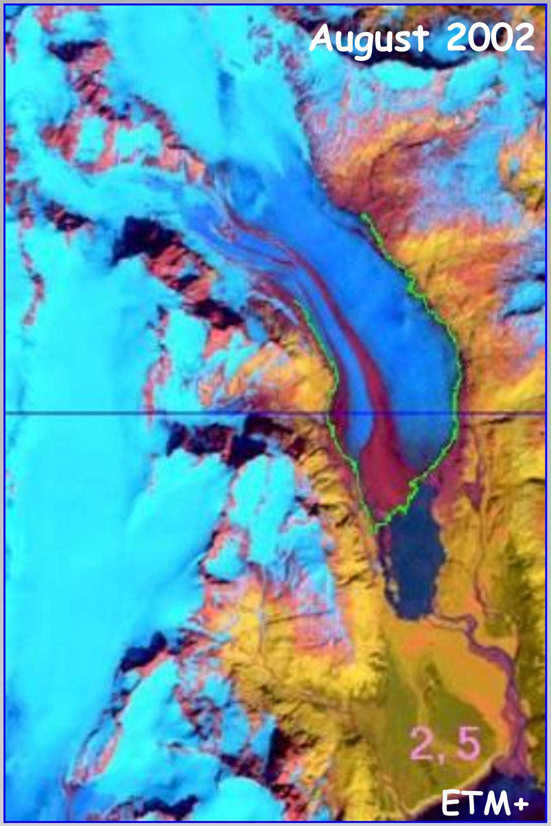
1994 air photo

ETM+ band 8
(15-m resolution)
9 August 2002


KENAI
NUKA GLACIER
GLACIER
GLACIER
McCARTY FJORD
Nuka River
Storm Mountain
3793ft
1156m
Iceworm Peak
5800ft
1767m
Kvasnikoff Falls
James Lagoon
NORTH ARM
North Arm Public Use Cabin
Paguna Arm
Taroka Arm
TWO ARM BAY
Desire Lake
Cloudy Mountain
1810ft
552m
Thunder Bay
Delight Lake
Beauty Bay
McCarty Lagoon
Black Bay
Moonlight Bay
YALIK GLACIER
WEST ARM
Surprise Bay
PETROF GLACIER
Yalik Bay
BAY
RK
KACHEMAK BAY
STATE PARK
NUKA BAY
PYE ISLANDS
ALASKA MARITIME
NATIONAL
WILDLIFE REFUGE
EMAK BAY
NUKA PASSAGE
NUKA
ISLAND





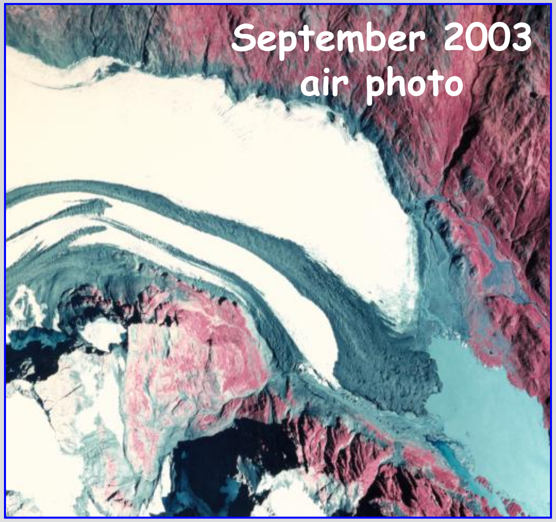


Yalik Glacier

1973

1986

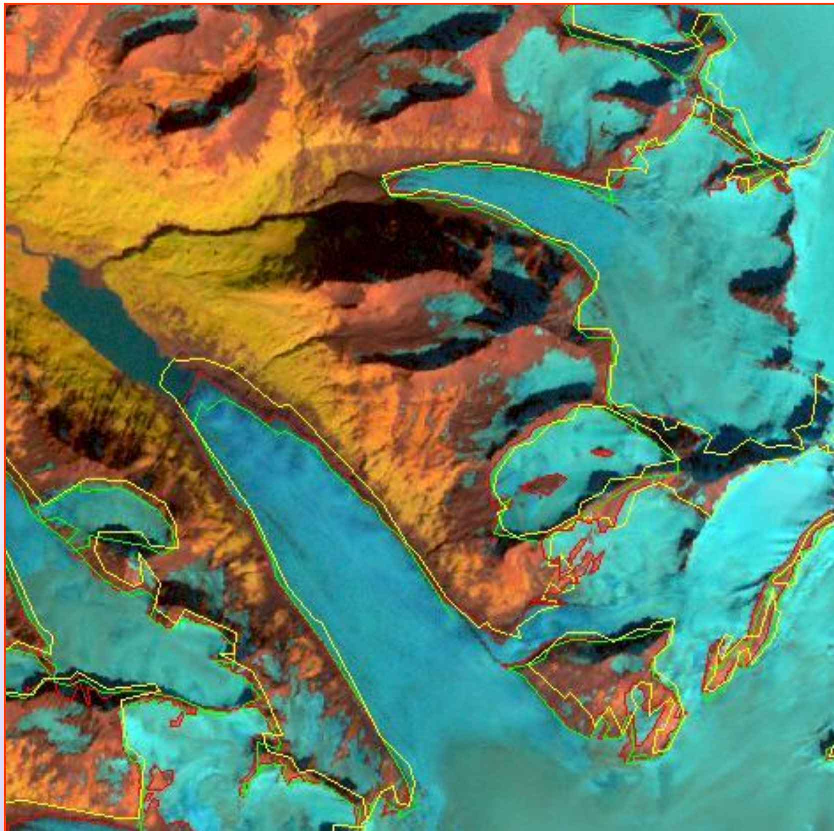
2002

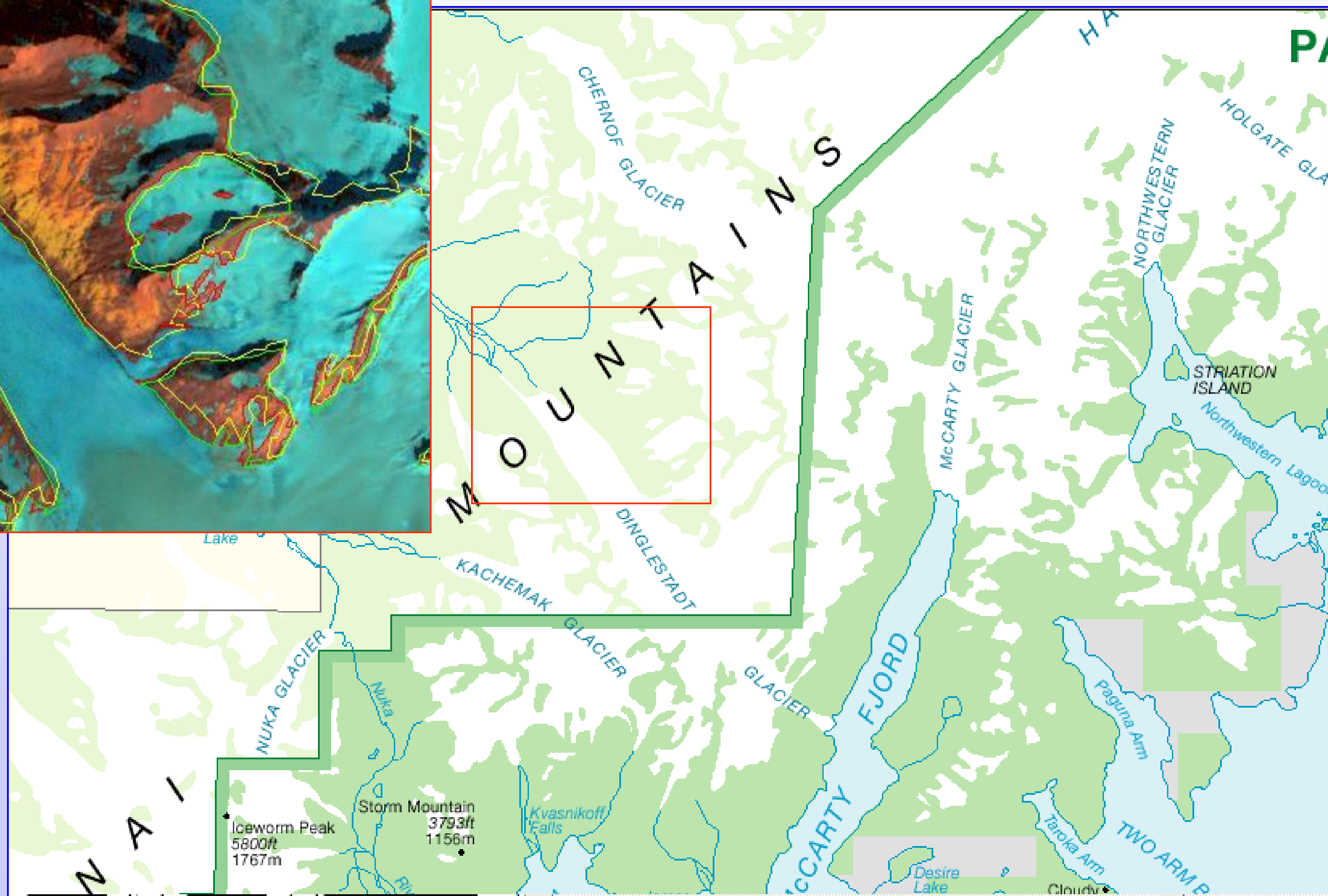


~1305±136 m recession from 1973-2002

Dinglestadt Glacier

~1040±136 m
recession from
1973-2002





1973

1986

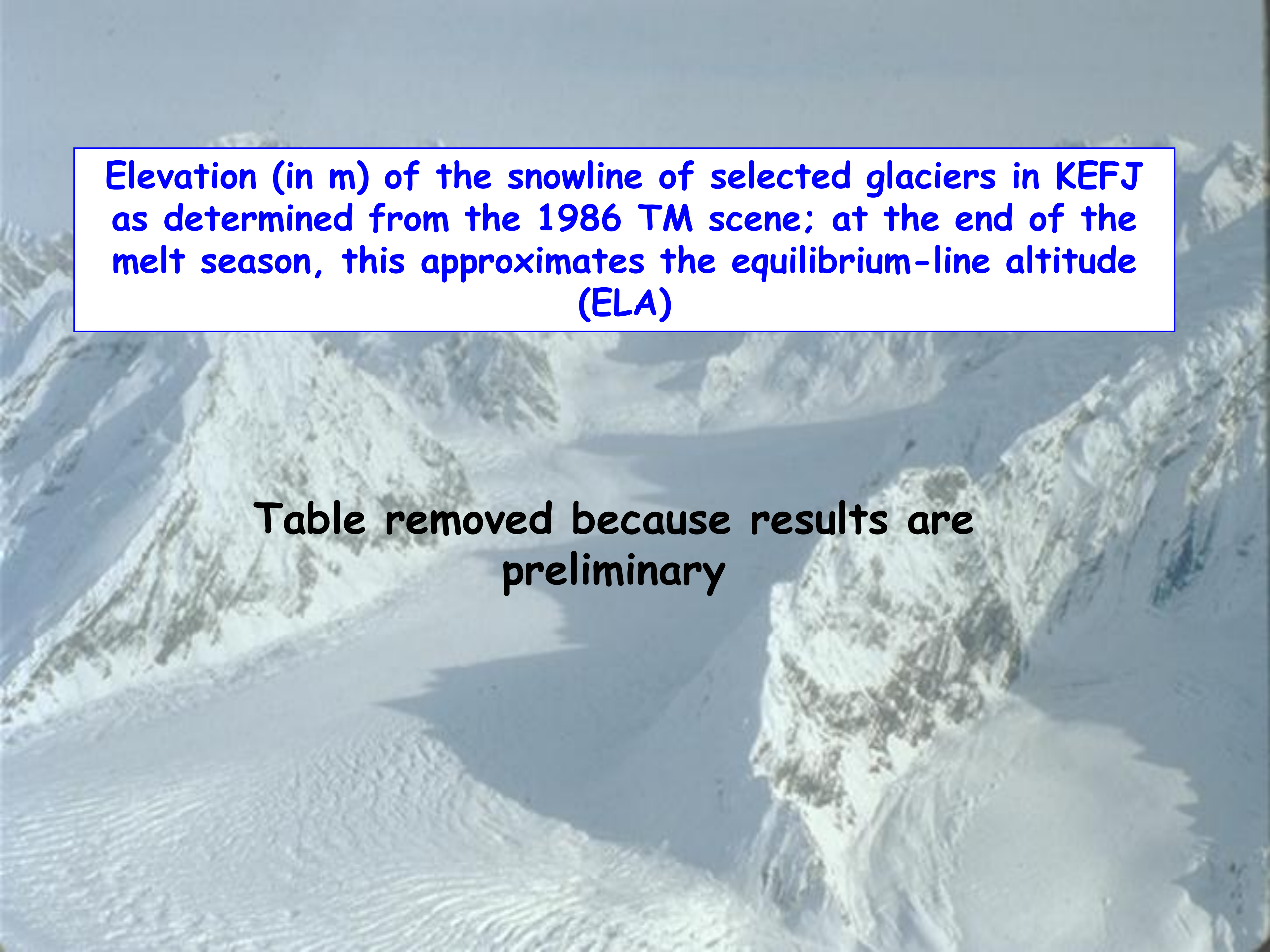
2002

Change (in m) of the terminus position of selected glaciers in KEFJ

Measurements will vary depending upon which point on the terminus is selected

Table removed because results are preliminary

1Terminates in tidewater
2Terminates in a lake
3Terminates on land
*Recession evident elsewhere on the terminus
4 Sapiano et al. (1998) reported a recession of –515 m of the Bear Glacier terminus, and a decrease in average thickness (-12.5 ±2.8 m) from 1957-1996, thus not in agreement with the change reported by Adalgeirsdóttir et al. (1998).
5 Not reported

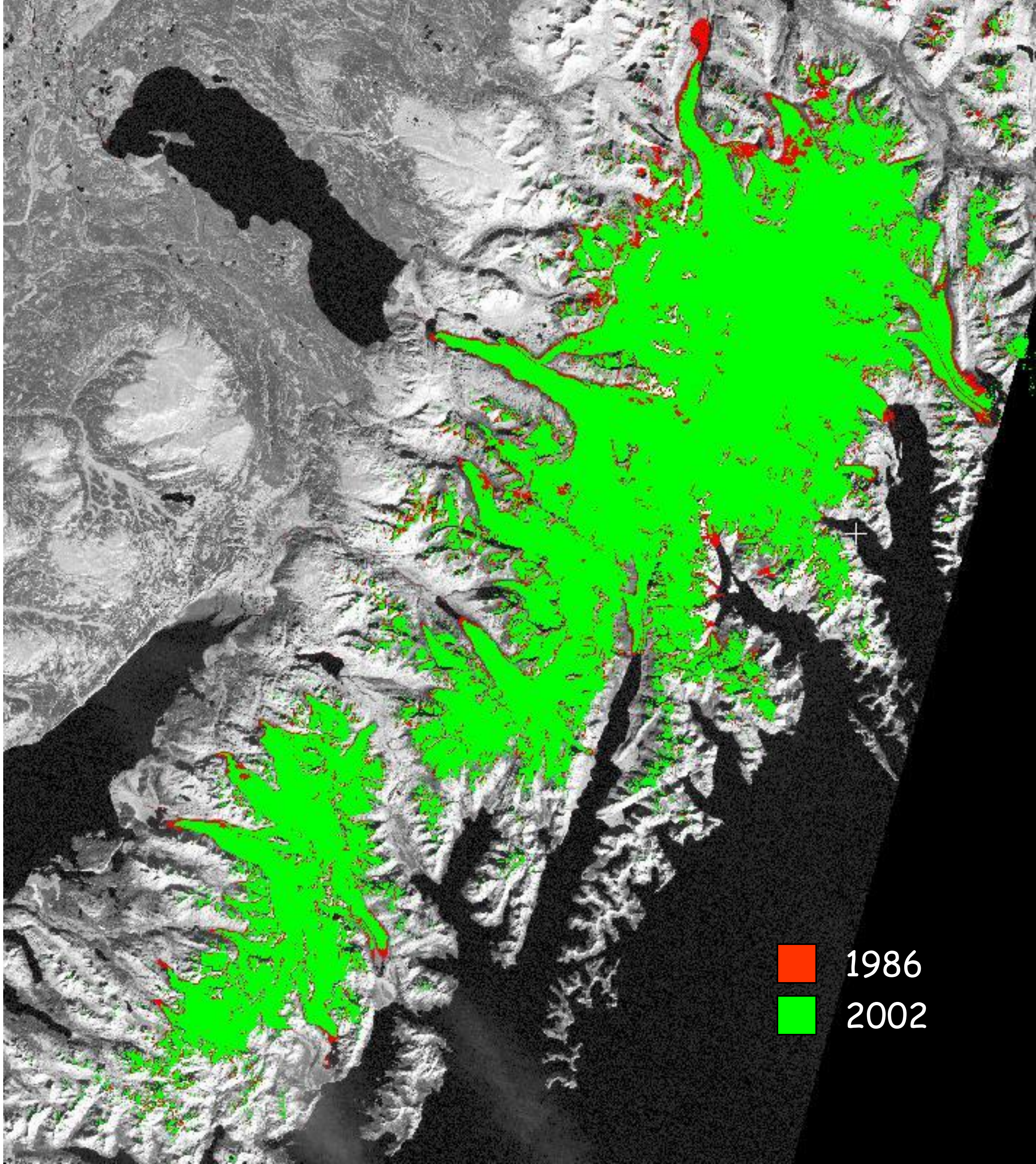


Elevation (in m) of the snowline of selected glaciers in KEFJ as determined from the 1986 TM scene; at the end of the melt season, this approximates the equilibrium-line altitude (ELA)

Table removed because results are preliminary

Change in areal extent from 1986 to 2002, as measured from Landsat images

Table removed because results are preliminary

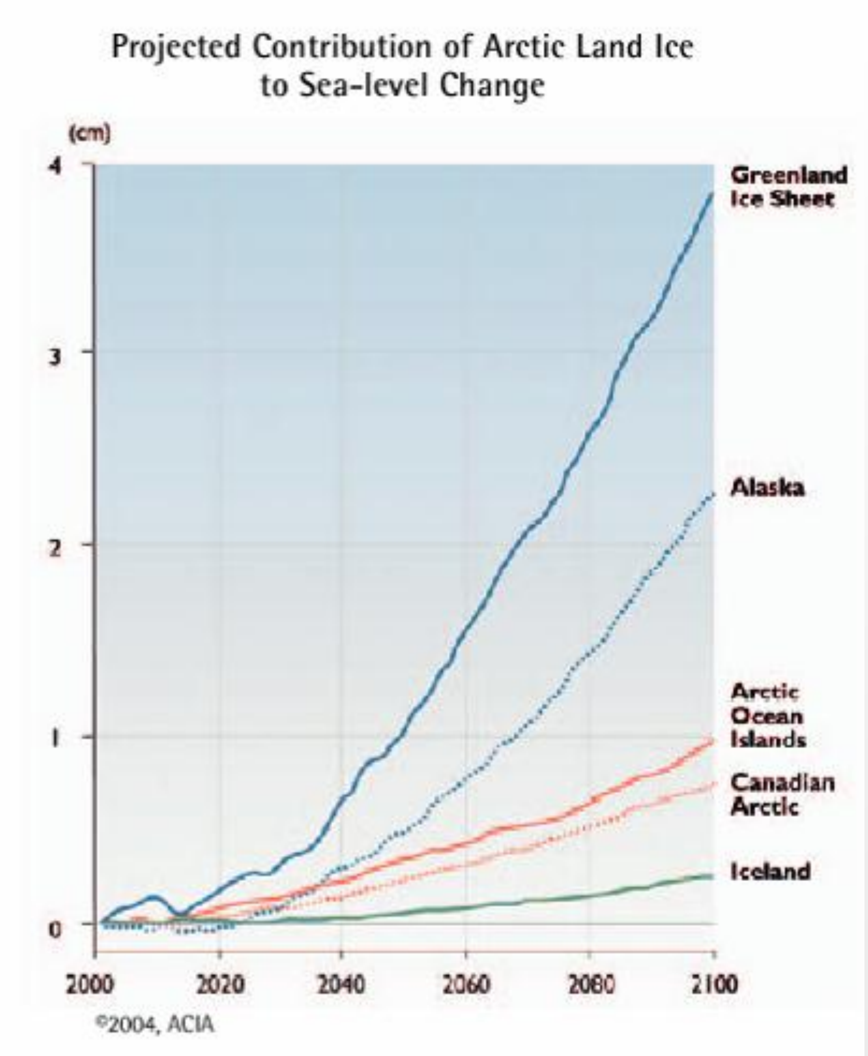


Contribution to Sea-Level Rise (SLR) of Alaska Glaciers

Alaska glaciers contributed about 9% of the observed rate of SLR (1.5 ± 0.5 mm/yr) over the past 50 years, and about 8% or more of the increased rate of SLR over the past decade (Arendt et al., 2002)

Alaska glaciers have made the largest single glaciological contribution to SLR over the past 50 years

(Arendt et al., 2002)



Issues & Recommendations

- Debris cover can mask the glacier terminus especially in the case of retreating glaciers
- Snowfall can mask the ELA (firn limit at the end of the melt season), and can make small glaciers appear larger
- A glacier can advance and thin and vice versa; thus terminus movement is only one indicator of glacier mass balance
- Publish results & provide shape files to the Global Land Ice Measurements from Space (GLIMS) project at the National Snow and Ice Data Center for the GLIMS global glacier database
- Work with GLIMS project to use the GLIMS protocol for measuring glaciers (under development)
- Register air photos to the Landsat images to resolve some issues related to debris-covered termini

Conclusions

- Results are provided in the form of GIS shape files derived from summer 1973, 1986 and 2002 Landsat images
- Most tidewater, land-terminating and lake-terminating glaciers in KEFJ receded between 1973 and 2002, as measured using Landsat MSS, TM and ETM+ data; tables are provided giving terminus changes on many of the KEFJ glaciers, and the elevation of the firn limit on selected glaciers in 1986
- Area measurements show a -40 ±0.0023 km^2 reduction in area of the glacier ice from 1986 to 2002
- These results confirm, and extend the extensive work done on the Harding Icefield in the mid- to late-1990s by University of Alaska scientists, though they also measured changes in glacier volume

Future Plans- Two Options

Continue with KEFJ work to do a complete analysis:

- Register ASTER data and air photos to the Landsat data
- Provide shape files for the glacier termini of the major glaciers from the air photos and ASTER images that are available
- Study available meteorological data in the context of glacier changes

Move on to Katmai National Park followed by Lake Clark National Park & Preserve

- Develop shape files of the glaciers from Landsat imagery in the 1970s, 1980s and 1990s or early 2000s (depending on image availability)